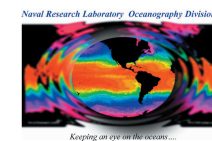# Photosynthetically Available Radiation (PAR) in the Navy Coastal Ocean Model (NCOM):
Ecosystem Sensitivity to PAR Temporal/Spatial Resolution

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INTRODUCTION

We examine the sensitivity of a coupled bio-physical simulation model to photosynthetically available radiation (PAR) fields, and their temporal resolution, used to force the model's biological component in the California Current System (CCS) of the Eastern Pacific Ocean off the West coast of the United States. A regional, high-resolution, circulation model (NCOM) nested within the global Navy Coastal Ocean Model (NCOM) has been coupled to the nine-component ecosystem model of Chai et al. (2001, Dugdale et al., 2001) and modified for this temperate coastal system.
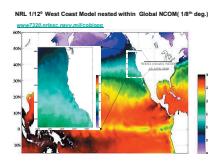
MODEL DESCRIPTIONS

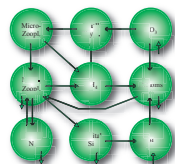Figure 1. NCOM-CCS domain.

Figure 2. The ecosystem model.

The Naval Research Laboratory (NRL) has developed the Navy Coastal Ocean Model (NCOM) for application to coastal and global prediction of ocean dynamic and thermodynamic fields. The NCOM model is a flexible variant of the Princeton Ocean Model (POM) that includes a hybrid vertical coordinate system as well as several options for mixing and boundary conditions. The Global NCOM model, developed and implemented by NRL, is presently in the final stages of validation and evaluation for operational use (Rhodes et al, 2001). This model runs using 1/8th degree horizontal resolution and 40 vertical levels that are a combination of sigma levels in the upper 150 m of the ocean and z-levels from 150 m to the ocean bottom. Global NCOM has been spun up from a climatological state to the present and assimilates altimeter observations and 3-dimensional temperature and salinity observations derived from the Modular Ocean Data Assimilation System (MODAS).

The NCOM-CCS (California Current System) model, which receives boundary information from the real-time global NCOM model described above is currently run with a grid resolution of 1/12th degrees and 30 sigma levels in the vertical (Shulman et al., 2004). The model domain extends from 30N to 50N and from 115W to 135W. This regional model for the US west coast also includes a 9-component ecosystem; the biological model was implemented into NCOM in collaboration Dr. Fei Chai (Chai et al, 2002, Dugdale et al., 2002). The biological model, originally developed for the equatorial Pacific upwelling system, includes three nutrients (silicate, nitrate and ammonia), two phytoplankton groups (diatoms and small phytoplankton), two groups of zooplankton grazers (micro- and meso-), and two detrital pools (silica and nitrogen). The model is capable of including or providing boundary values to sub-nests at very high resolution for specific domains along the coast. This model is forced by high resolution surface fluxes as provided by the COAMPS Eastern Pacific Reanalysis product (Kindle et al., 2002, GRL) which exists on a triply nested 81/27/9 km grid beginning in November of 1998 and are generated in collaboration with the Marine Meteorology Division of NRL.

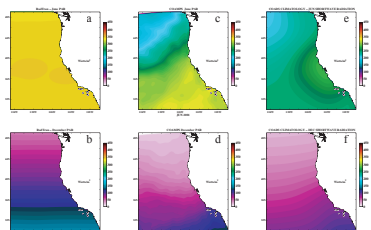## PHOTOSYNTHETICALLY AVAILABLE RADIATION

Figure 3. Examples of PAR fields used. June (top row) and December (bottom row). for RadTran (first column), COAMPS (second column), and COADS (third column).

We used PAR fields from three sources for the study. First, we used Gregg and Carder's (1990) clear-sky radiative transfer model (RadTran) to compute both daily averaged and hourly PAR values for every grid cell of the NCOM-CCS domain (Figures 3a and 3b). Figure 4 plots both the daily maximum PAR (top curves) and the daily averaged PAR (bottom curves) each day for a two-year period for latitudes 33°N to 49°N. Note that the variability over the latitude range of daily averaged PAR in the summer is much smaller than either the wintertime variability or variability of the daily maximum. This is due to the tilt of the Earth's axis giving longer day lengths (photoperiod) in northern latitudes. These modeled values represent hypothetical maximum values. Next, monthly climatological PAR was obtained from the shortwave radiation (SW) fields (PAR = 0.45 SW) of the Comprehensive Ocean-Atmosphere Data Set (COADS) and interpolated to daily values over the grid (Figure 3e and 3f). Lastly, the COAMPS (Coupled Ocean Atmosphere Mesoscale Prediction System) Reanalysis atmospheric model for the Eastern Pacific supplied hourly solar shortwave radiation values at the ocean surface (Figures 3e and 3f). The COADS and COAMPS products provide radiation fields that include meteorological (i.e., clouds and fog) effects (Figure 5).

Two sub-regions of our domain were used for this study: the Oregon coast (ca. 44°N) and the Monterey Bay, California region (ca. 36°N).
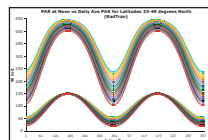

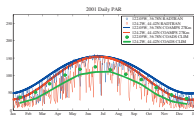Figure 4. RadTran computed PAR (see text).

Figure 5. 2001 daily PAR at the two study regions.

MODEL VALIDATION:

The model sufficiently reproduces observations (Figures 6-11) along the U.S. West coast to be useful in our examination of PAR forcing. Forcing the coupled ecosystem with hourly COAMPS PAR provided the best match to observations, these results are shown below. The differences between the results for various products are shown to the right (Figures 12-15).
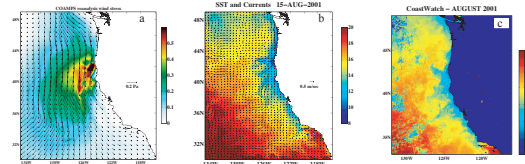
PHYSICAL CIRCULATION

Figure 6. COAMPS Reanalysis winds for 8 August, 2001 (a), model sea surface temperature (SST) (degrees C) and surface currents on 15 August, 2001 (b), and NOAA CoastWatch August, 2001 composite satellite image of SST (c).
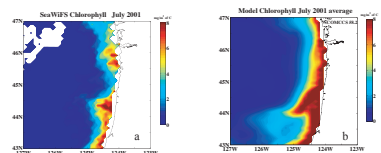
COUPLED ECOSYSTEM

Figure 7. SeaWiFS chlorophyll image (a) and model chlorophyll (b) for the Oregon coast region.
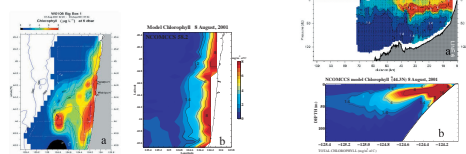

Figure 8. Surface chlorophyll in the Oregon coast region (8 August, 2001). Shipboard measurements (a) and model results (b). Data courtesy of Jack Barth, and COAST.

Figure 9. Chlorophyll profile at 44.3 N (8 August, 2001). Shipboard measurements (a) and model results (b). Data courtesy of Jack Barth and COAST.
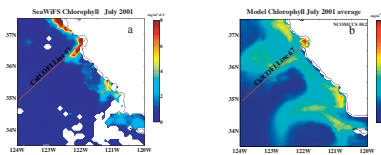

Figure 10. SeaWiFS chlorophyll image (a) and model chlorophyll (b) for the Monterey region. With the approximate location of CalCOFI Line 67 drawn.
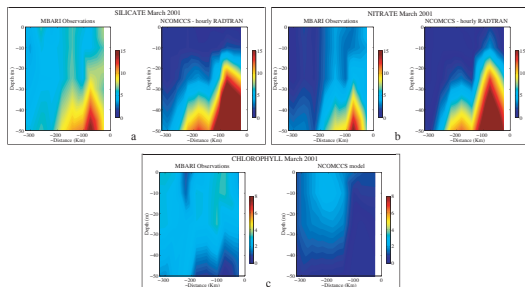

Figure 11. MBARI cruise data (left) and model results (right) from CalCOFI line 67. Silicate (a), nitrate (b) and chlorophyll (c). Line 67 data courtesy of Francisco Chavez, MBARI.

RESULTS

TEMPORAL RESOLUTION

The coupled ecosystem model was most sensitive to changes in the PAR temporal resolution. Daily mean PAR values at each time step, rather than the hourly value, produced more sub-surface and near-shore chlorophyll. The hourly PAR simulations had larger off-shore surface values. These differences were apparent for both RadTran (not shown) and COAMPS (Figures 12-14) experiments.

Figure 12. Integrated chlorophyll (mg chl m^{-2}) to 50 meters averaged over near-shore regions in Oregon (a) and Monterey (b). Daily averaged (blue) vs. hourly (red) COAMPS. [Model spin-up may influence the springtime bloom; current, longer term runs will address this issue].
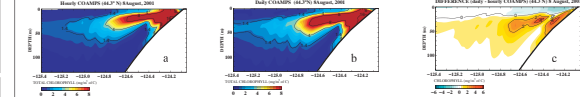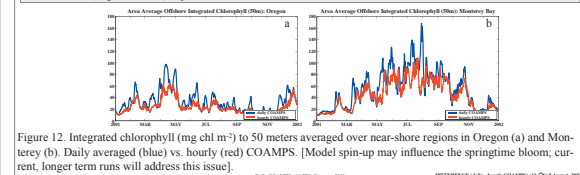

Figure 13. Profiles of chlorophyll at 44.3N 8 August, 2001 for (a) hourly COAMPS PAR and (b) daily averaged COAMPS PAR, and (c) the difference between the two (daily - hourly).
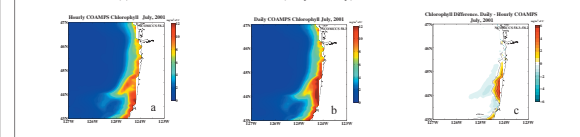

Figure 14. Surface chlorophyll off the Oregon coast for (a) hourly COAMPS PAR and (b) daily averaged COAMPS PAR, and (c) the difference between the two (daily - hourly).

DATA PRODUCTS

Although the magnitudes of the three different PAR data sources (RadTran, COADS, and COAMPS) were quite different (Figures 3 and 5), comparisons between different products at the same temporal scale show much less variation than the same products at different temporal resolutions. Hourly RadTran vs COAMPS integrated chlorophyll are shown (Figure 15) for the two sub-regions.
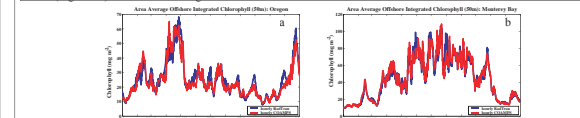

Figure 15. Integrated chlorophyll (mg chl m^{-2}) to 50 meters averaged over near-shore regions in Oregon (a) and Monterey (b). Hourly RadTran (blue) vs. hourly COAMPS (red).

CONCLUSIONS

The NCOM-CCS coupled ecosystem model adequately simulates the Eastern North Pacific Ocean off the U.S. West coast. While daily averaged and hourly products provide the same total amount of PAR to drive primary production, the temporal resolution has significant effects on the model solution. Due to the asymptotic nature of the growth curve with respect to light (P vs. E curve) phytoplankton response to the higher magnitude PAR received in the hourly solution does not lead to the same total production as in the daily average PAR solution (Figure 12). This also explains the similar total production achieved with different products at the same temporal resolution (Figure 15). The periods of darkness during the diurnal signal in the hourly forcing allow nutrients to be upwelled along the coast and advected farther offshore before being taken up by the phytoplankton (not shown). These phytoplankton blooms can then extend farther from the coast (Figure 14c). Daily averaged light allows nutrients to be taken up continuously and become depleted at the surface closer to the coast.

This work has been a useful step in our effort to develop a spectral bio-optical component for incorporation into the NCOM-CCS model system.

For more discussion of the NCOM-CCS model system see the poster (#56) by deRada et al. (this conference).

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